5.—Topographic Relationships of Laterite near York, Western Australia

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In the course of field studies of soils in an area extending eastwards from the Avon Valley, Western Australia, a number of erosional and depositional surfaces have been recognized. The older of these surfaces are lateritic. This paper presents an account of the distribution and relationships of the surfaces, and suggests a relative chronology for them. The soils associated with each surface are only briefly mentioned, as their characteristics will be reported in greater detail elsewhere.

The area studied is that shown in Fig. 2. The town of York, which lies in the southwest corner is 60 miles east of Perth. The country rocks are the Precambrian granites and gneisses of the West Australian Shield, with occasional basic intrusions (Wilson 1958). The general pattern of the drainage is controlled by the geological structure, and the main streams are the north-flowing Avon River, the south branch of the Mortlock River flowing northwestwards across the area to join the Avon, near Northam, and the south-flowing salt lake system east of Quairading.

The climate is of the Mediterranean type, with hot dry summers, most of the rain falling during the winter. At York, the average annual precipitation is 18 in., falling to 13.5 in. at Jennaberring, just beyond the eastern boundary of the area†.

It appears that the dominant process of slope formation has been by parallel scarp retreat, giving typical "breakaway" country. To a considerable degree, the erosional products of the breakdown of the lateritic surfaces have been removed from the system. This means that, in contrast to the higher rainfall country of the Darling Range to the west, the lateritic surfaces are sharply defined by topographic features. In the wetter country, on the other hand, though the landscape is deeply dissected, lateritic detritus in the form of yellow sands, ironstone gravels and boulders mantles most of the slopes and many valley floors. Often, too, this detrital laterite (Woolnough 1927) is recemented with iron oxides into massive pavements, rendering the various surfaces difficult to recognize.

For convenience, each surface in the area studied has been named, using appropriate local place names. The detailed field relationships of the surfaces recognized are shown in Fig. 1.

The *Quailing* surface occupies the highest parts of the landscape, and carries what may be presumed to be the oldest laterite. The surface soil is a yellow sand or sandy loam over ferruginous concretions, which in turn overlie the usual mottled and pallid zones, the latter being of the order of 15 feet deep. Massive laterite pavements are relatively limited in extent, occurring mainly along the breakaway edges or at the crests of slight rises. Work carried out in association with the University of Western Australia indicates that the surface yellow sands and the ferruginous concretions beneath them contain appreciable amounts of easily weatherable minerals (Morgan and Herlihy 1956) which are almost completely absent from the underlying pallid zones, though present in the parent rock. It appears, therefore, that with the formation of the ironstone, inclusions of only partly weathered rock may be protected from further weathering, and these inclusions can occasionally be observed in the field. Further, apart from slight organic staining, the surface yellow sand shows no profile differentiation, though bleaching of the sand grains to give a grey A_2 horizon would be expected to take place fairly quickly. It is therefore suggested that although the Quailing surface is old, the soil developing thereon is relatively young, and that its parent material is the ferruginous horizon of the Quailing laterite.

Downslope from the Quailing erosional surface are accumulations of deep yellow sand with some soft, round, reddish brown mottles, which, as Prider (1946) has suggested, may be ferruginous concretions in the course of formation. The soils otherwise show an undifferentiated profile, with the same assemblage of easily weatherable minerals as in the laterite above. The deep yellow sands are therefore considered to be a colluvial deposit derived from the erosion of the Quailing surface, and the corresponding erosional and depositional surfaces are shown in Fig. 1.

The *Kauring* surface generally lies about 20 feet below the level of the Quailing erosional surface, occupying wide, flat-floored valleys cut in the latter. The soil is a grey sand overlying a massive ironstone, paler than that of the Quailing surface, and has been occasionally observed to carry inclusions of kaolinised rock. Normal pallid zone clays lie beneath. In contrast to the Quailing sands, these grey sands contain very few easily weatherable minerals. This soil therefore, appears to correspond with the intact laterite profile such as the Eleanor sand described by Northcote (1946) from Kangaroo Island, but it is to be noted that it occupies the floors of shallow valleys cut in the Quailing surface, while the inclusions of pallid zone in the ferruginous horizon indicate formation in already weathered material. It is concluded, therefore, that the Kauring laterite is younger than the Quailing laterite.

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† Book of Normals, Commonwealth Meteorological Branch.

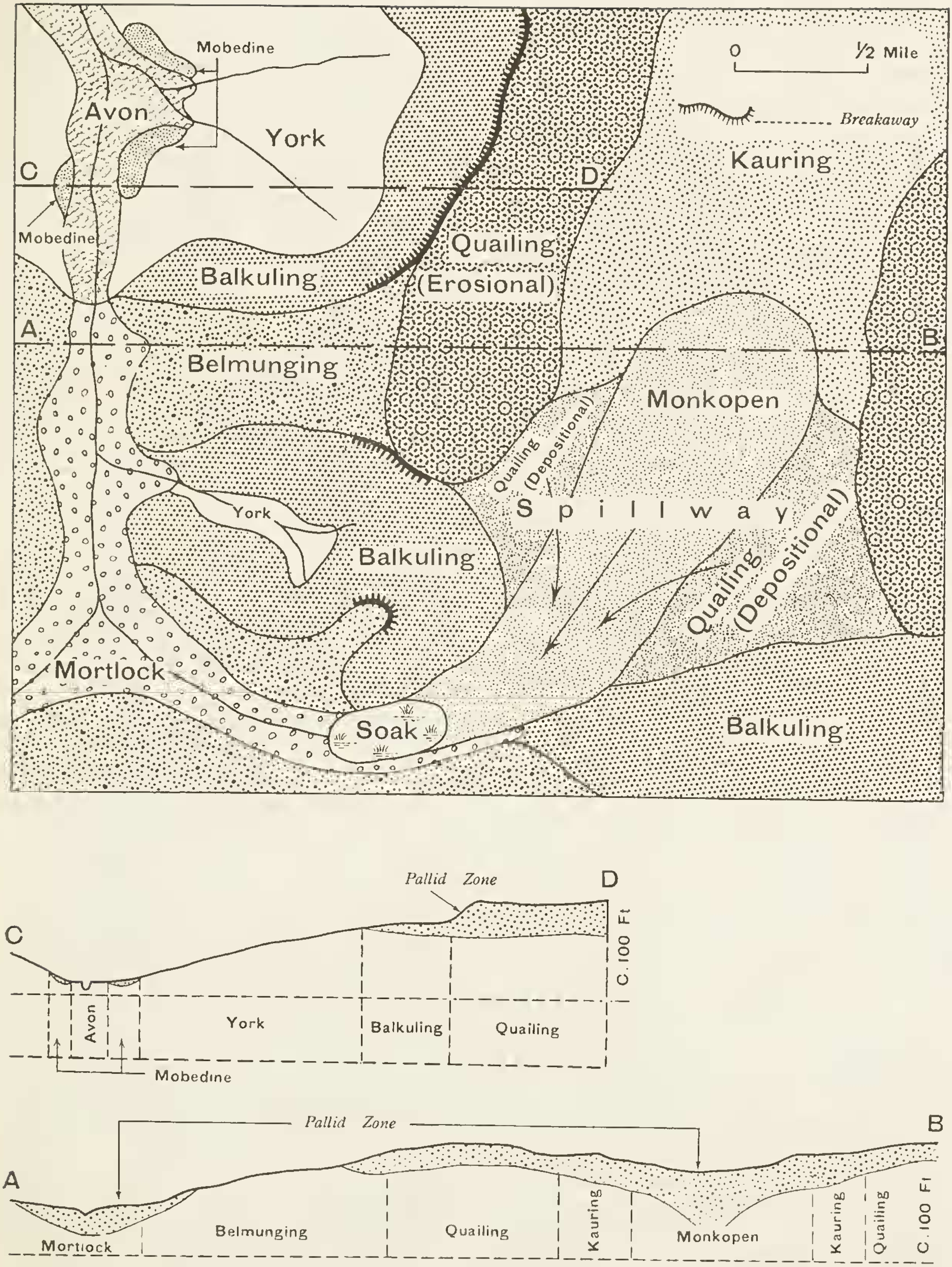

Fig. 1.—Detailed distribution of the surfaces.

The *Monkopen* surface occupies deep sandy hollows originating at high level in the Kauring surface. The sands are grey at the surface, becoming pale yellowish brown with depth. The texture may rise to sandy loam with some small ferruginous concretions at about three feet, and this horizon may be waterlogged in winter, in contrast to the soils of the surfaces already described. At depth the material resembles the Quailing yellow sands. As shown in Fig. 1, the Monkopen surface sweeps down from high level, passing through gaps in the line of breakaways like a sandy avalanche, being joined by the yellow sands from the Quailing surface on route. Thus, the features together have been referred to as "spillways" and particle size studies show that the material has been transported. The sorting coefficient of the sand (Twenhofel and Tyler 1941) near the top of the spillway is 2.0 decreasing to 1.4 at the bottom. This indicates that the sands in the lower positions are more sorted, and therefore must have moved farther than those above. They commonly end in soaks which are often permanent supplies of good quality water. The depth of the sand varies, tending to be deepest, 50 feet or more, towards the centre of the spillway. Evidence from bores and wells shows that there may be more than one band of ferruginous concretions, possibly indicating a number of depositional periods separated by soil forming periods. The Monkopen and Quailing sandy deposits usually overlie pallid zone material, but they occasionally overlie other soils as will be described below.

The "Old Plateau" of Western Australia (Jutson 1950) has been regarded by a number of workers (Woolnough 1927, Prescott 1952, Stephens 1946) as having been formed during one or more epochs of the Tertiary. The evidence presented here suggests that the oldest surfaces, i.e. the Quailing and Kauring surfaces, represent this Tertiary laterite of Western Australia, which thus appears to have formed in two stages. It has undergone considerable modification as evidenced by the Monkopen depositional material which has not been carried out of the system, and further, this kind of modification has continued up to fairly recent time, resulting in the stripping of the Quailing surface and the deposition of the yellow sand below it. The surfaces now to be described represent the sides and floors of valleys formed by the erosion of the "Old Plateau".

The Quailing and Kauring surfaces, except where breached by spillways, are in general bounded by a break in slope. Where the break is a minor one it forms the upper limit of the *Belmunging* surface (Fig. 1) which extends as lateritic spurs and ridges sloping at an angle of 2° or steeper, down towards the drainage lines. The soil consists of a greyish brown sand with ferruginous concretions over a reddish brown and yellowish brown mottled clay which hardens when exposed in ditches and cuttings. The pallid zone is commonly absent except at the down slope limit, the profile passing into the country rock at about 8 feet.

Downslope the Belmunging surface gives way to flat valley floors forming the *Mortlock* surface. The soils here are similar to those of the Belmunging ridges though less well drained and with greyer colours in the surface. Beneath the ferruginous zone there is, however, an appreciable though variable depth of pallid zone often

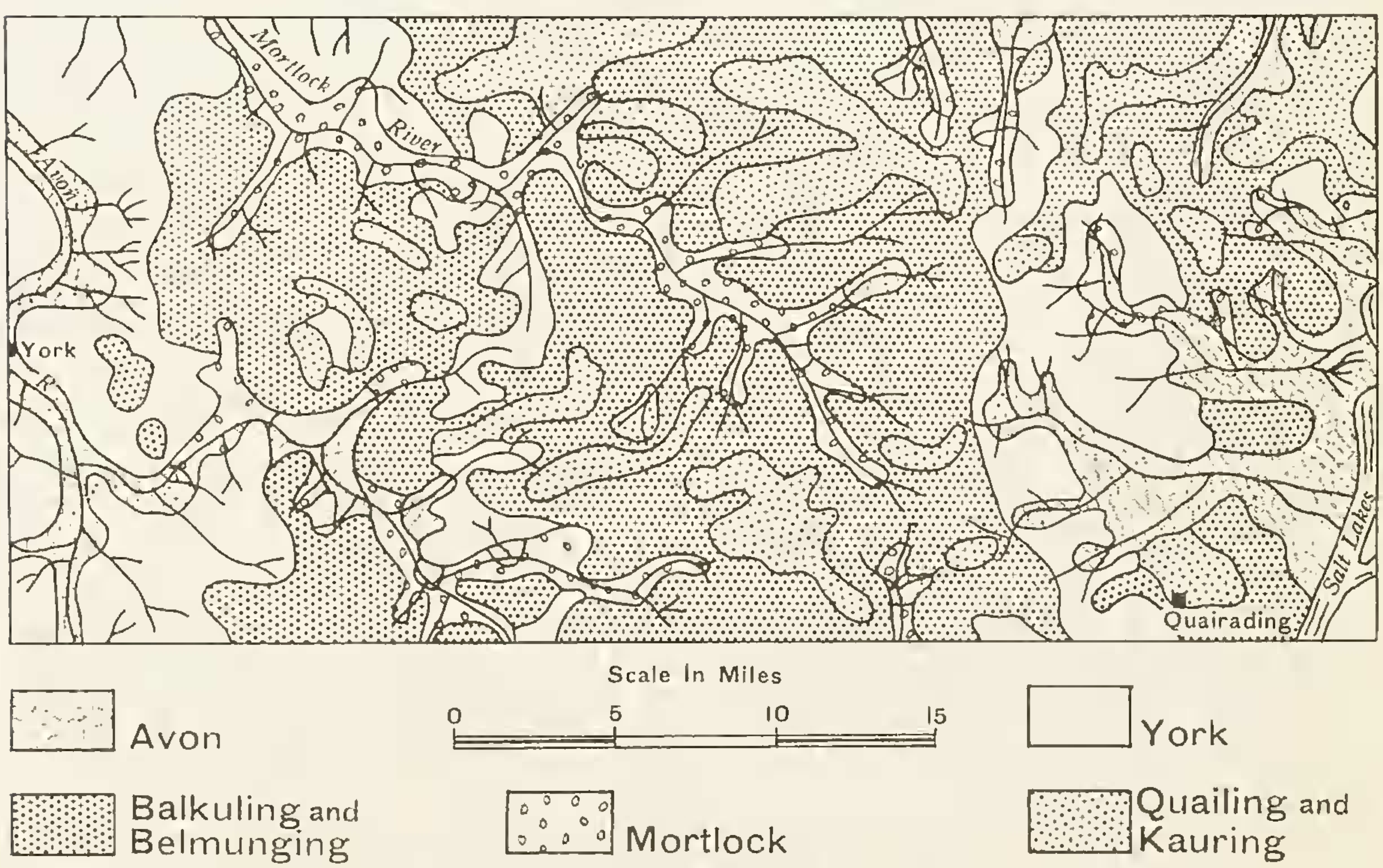

Fig. 2.—General distribution of the surfaces.

recognizable as a kaolinised coarse water-laid sediment. Thus the Belmunging and Mortlock surfaces represent the sides and floors of old valleys cut in the Tertiary surface. (Fig. 1, Section AB.)

The destruction of the Quailing, Kauring and Belmunging surfaces is proceeding by the retreat of scarps which are actively eroding at the present day. The scarps are the breakaways which are such a feature of this and other parts of Western Australia, and have been already described by many workers, e.g., Walther (1915). The pediment, which slopes away at an angle of about 1° or more from the foot of the breakaway, is essentially a cut surface (King 1949); in this case cut in pallid zone or weathered rock (see Fig. 1, Section CD), and has been named here the *Balkuling* surface. The soils are pale greyish or pinkish clays, often overlain by a greyish brown quartzose sandy and gritty pedisediment, decreasing in depth with distance down the slope. Where it adjoins a spillway the Balkuling surface can be seen to pass under and to be buried by the yellow sand of the Quailing depositional surface, and occasionally by the grey sand with an ironstone gravel horizon of the Monkopen surface. Thus it predates the former, and part at least of the latter deposit.

Below, the lower limit of the Balkuling surface is marked by a slight increase in slope, which is also the upper limit of the *York* surface. This is characterised by outcrops of unweathered rock, with associated shallow skeletal soils, and, particularly in the Avon Valley, by deeper soils consisting of brown sandy loams over reddish brown clays, with fresh rock fragments throughout the profile. The latter, though usually non-calcareous, are the so-called red-brown earths of Prescott (1931), and later Teakle (1938). The soils of the York surface have not been intensively studied, and may, in fact, judged by the criteria of Butler (1958), consist of a complex of surfaces of different ages. Nevertheless, the distribution of the York surface in proximity to active drainage lines suggests that the complex as a whole represents a cycle of erosion cutting into the Balkuling and Belmunging surfaces. The depositional material of the valley floors associated with the York surface has been called the *Avon* surface, and carries brown and grey fine textured calcareous soils, the solonised brown and solonised grey soils of Teakle (1938). However, in all the valleys examined the solonised grey and brown soils overlie kaolinised coarse waterlaid sediments which appear to be the eroded stump of the Mortlock lateritic surface. Thus the Avon and York surfaces are established as being younger than the Mortlock and Balkuling, and hence the Belmunging surfaces.

It remains to mention one further feature, namely, the *Mobedine* surface. This appears to be confined to the Avon Valley, where it is found at or about the 600 foot contour from near York downstream to beyond Toodyay, a distance of about 50 miles. It occurs as a scree forming the noses of ridges as shown in Fig. 1. Each rock fragment, however, has a coat of iron oxide, which in some instances cements the material into massive laterite-like boulders. It may overlie reddish brown and yellow mottled clays resembling the subsoils of the Belmunging surface, or relatively fresh rock. Its age remains uncertain at the moment, though it is tempting to suggest that it lies somewhere between the Belmunging and York surfaces.

The general distribution of the surfaces over the whole area is illustrated in Fig. 2, and it is again apparent that their pattern of occurrence is closely controlled by the erosional history. The latest erosional cycle recognized has worked headwards up the Avon Valley and its tributaries, stripping the Belmunging surface from the valley sides, while the stumps of the Mortlock surface are buried in the valley floors. Beyond the limits of this cycle the Belmunging surface dominates the valley slopes. The Quailing and Kauring surfaces occupy the divides, and the Balkuling surface is extending by headward erosion at the expense of the three older surfaces.

The distribution of the older surfaces in relation to the drainage system of the Avon to the west, and the salt lakes beyond Quairading to the east, and the fact that on the regional as well as the local scale the Quailing and Kauring laterites dip towards the drainage lines suggests that even as far back as Tertiary times these drainage systems or their precursors were in existence. Subsequently, the Belmunging and Mortlock surfaces, so well preserved in the present Mortlock River valley flowing northwestwards across the area, were formed. The map (Fig. 2) shows that the latest cycle of erosion recognized, that responsible for the York erosional surface and the Avon depositional surface has to some extent invaded the catchment of the Mortlock system both from the east and the west.

The York cycle is working back, however, not only from the Avon Valley, which drains to the sea, but also from the tributaries of the Mortlock, upstream of the Mortlock surface, and from the head waters of the distributary streams which feed the salt lake systems to the east. While epeirogenic uplift may account for the first case, that of the Avon Valley, it cannot account for the latter two, which are working to local base levels. Thus some other factor, possibly a climatic one, must be involved. According to Penck (1953) an increase in rainfall may increase rates of down cutting by streams, but the widely distributed remnants of the Mortlock layer in the valley floors preclude this explanation. On the other hand, the work of Butler (1958) correlates instability of slopes with arid conditions and does not necessitate the removal of the older deposits in the valley floors, but rather their burial by younger sediments.

It is hoped to extend similar studies of the relationship of soils and land surfaces to representative areas of southwestern Australia, and correlation with the depositional systems and soils of the Swan Coastal Plain, for which McArthur and Bettenay (in press) have suggested an absolute chronology, may be possible. Thus may be achieved an understanding not only of the erosional history but also of one of the main factors governing the pattern of distribution of the soils.

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